Appendix 3
Correction for the Effects of Background Noise

A1.1 Introduction:

The presence of background noise during aircraft noise certification tests can influence measured aircraft sound levels, and in some cases, obscure portions of the spectral time history used to obtain EPNL values. Correction procedures must be performed which include the following components:

- Testing to determine which, if any, portions of the spectral time history are obscured.
- Correcting unobscured levels to determine the aircraft sound levels that would have been measured in the absence of background noise.
- Replacing or reconstructing obscured levels by extrapolation or other means.

A1.2 Definitions:

Note that terms defined here will appear in the text in italicized type and capitalized as follows: Background Noise.

- Background Noise - Noise from sources other than the test aircraft, which can influence or obscure the noise levels being measured. Per Advisory Circular 36-4B (Reference 3.c), Background Noise is comprised of Pre-Detection and Post-Detection Noise.
- Pre-Detection Noise - Any noise which can add on an energy basis to the levels of noise produced by the aircraft, including Ambient Noise and active electronic instrumentation Floor noise.
- Post-Detection Noise (or Minimum Valid Levels) - Not actually noise, per se, but rather the minimum levels below which measured noise levels are not considered Valid. Usually determined by the baseline of an analysis "window", or by amplitude non-linearity characteristics of components in the measurement and analysis system.
- Ambient - Acoustical background noise present during measured aircraft events. Traditionally, this term has been used interchangeably with Pre-Detection Noise, which included additive instrumentation Floor noise.
- Floor - A one-third-octave-band spectrum of the lowest levels that can be measured, recorded or quantified by components in the measurement and analysis system. Traditionally, this term has been used interchangeably with Post-Detection Noise, which can be a source of confusion, since most instrumentation noise floors have additive characteristics.
- Energy-Subtraction - Subtraction of one sound pressure level from another, on an energy basis, in the form:
  $10*\log_{10}[10^{(A/10)}-10^{(B/10)}]$ Where A and B are two sound pressure levels in decibels, which are subtracted.
- Masking Criteria - The spectrum of one-third-octave-band levels that represent the levels below which measured aircraft sound pressure levels are considered to be Masked or obscured (i.e., unusable) by Background Noise. FAR 36 Masking Criteria are defined as the greater of: 1.) Pre-Detection Noise +3 dB (+5 dB for helicopters); or 2.) Post-Detection Noise +1 dB. Note that proposed harmonization with ICAO regulations may result in these criteria being changed to Pre-Detection Noise +3 dB and Post-Detection Noise +3 dB for all aircraft.
- Masked (Level) - Any one-third-octave-band level which is less than or equal to the Masking Criterion for that band. When a level is identified as being Masked, the actual level of aircraft noise in that band cannot be determined. Masked Levels can be reconstructed using extrapolation or other methods.
- Valid or Unmasked (Level) - Any one-third-octave-band level which exceeds the Masking Criterion for that band.
- Reconstructed (Level) - A level, calculated by extrapolation or other means, which replaces a measured Masked Level.
- Adjusted (Level) - A Valid Level, which has been corrected for: 1.) The energy contribution of Pre-Detection Noise; and 2.) frequency-dependent corrections for measurement conditions, including system frequency-response, microphone pressure-response and free-field response, windscreen incident-dependent insertion loss, and analyzer bandwidth error.

- High-Frequency and Low-Frequency Bands - For the purposes of this procedure, the 24 one-third-octave-bands of interest are categorized as follows: Low-Frequency: 50 Hz through 630 Hz inclusive; and High-Frequency: 800 Hz through 10 kHz inclusive.
- LGB (Last Good Band) - In the example correction methodology presented (see Paragraph A1.4), for any aircraft one-third-octave-band spectrum, the highest-frequency band within the range of 630 Hz to 10 kHz inclusive, below which there are no masked High-Frequency Bands.

A1.3 Assumptions:

- Aircraft noise measured on the ground has a characteristic high-frequency roll-off, due to the effects of atmospheric absorption as well as other effects. A typical aircraft spectrum measured on the ground contains one-third-octave-band levels which decrease in amplitude as they increase in frequency.
- Electronic instrumentation floors typically exhibit a more or less random distribution of energy over frequency with increasing levels in higher-frequency one-third-octave bands.
- Due to the aforementioned characteristics, as the observed frequency is increased within a one-third-octave-band spectrum, once a band becomes Masked, subsequent bands will also be Masked. This allows the implementation of a “Last Good Band” label to identify the frequency band above which the bands in a spectrum are Masked.
- If, on occasion, any Valid bands occur above LGB, their presence will most likely be due to small variations in the Pre-Detection Levels, and/or because the levels of the measured aircraft one-third-octave-band spectrum are close to the levels of the Background Noise in general, and therefore their energy contribution will not be significant (This assumption is only valid in the absence of significant aircraft-generated tones in the region of Masking). Therefore, the possibility of bands being Valid beyond LGB may be ignored in order to keep the correction process simple. Applicants who prefer to implement algorithms for identifying and handling such situations may do so, but any procedures must be validated by VNTSC and approved by FAA before use in an aircraft noise certification program.

Note: Limitations and requirements for all methodologies are described after the steps for the example background noise correction procedure (see Paragraph A1.5).

A1.4 Example Background Noise Correction Procedure:

Note: Steps 1 through 5 of this procedure are required, regardless of the methods used to correct for the effects of background noise.

1. Determination of Pre-Detection Noise; An average one-third-octave-band spectrum of Pre-Detection Noise levels for each event (or group of events occurring during a short time period) should be obtained by recording and analyzing Ambient noise over a representative period of time (preferably 30 seconds or more). Care should be taken to ensure that this Ambient noise truly represents that which is present during measured aircraft events. In recording Ambient noise, all gain stages and attenuators must be set as they would be during the aircraft events to ensure that the instrumentation noise is also representative. If multiple gain settings are required for aircraft noise measurements, a separate Ambient sample should be recorded at each setting used.
2. Determination of Post-Detection Noise: A one-third-octave-band spectrum of Post-Detection Noise levels should be determined as a result of testing (or from manufacturer’s specifications for recording or analysis equipment), for each measurement / analysis configuration used (including different gain and / or sensitivity settings). Minimum Valid Levels may be determined on the basis of display limitations (e.g., blanking of the displayed indication when levels fall below a certain value), amplitude non-linearity, or other non-additive limitations. In cases where more than one component or stage of the measurement / analysis system imposes a set of Minimum Valid Levels, the most restrictive in each one-third-octave-band should be used.
3. Testing of the Pre-Detection Noise vs Post-Detection Noise; The Validity of Pre-Detection Noise levels must be established. Any Pre-Detection Noise level which is equal to or less

than the Post-Detection Noise level in a particular one-third-octave-band should be identified as invalid, and therefore may not be used.

4. Determination of Masking Criteria; Once the Pre-Detection Noise and Post-Detection Noise spectra are established, the Masking Criteria can be identified. For each one-third-octave-band, compare the valid Pre-Detection Noise level +3 dB (Pre-Detection Noise +5 dB for Helicopters) vs the Post-Detection Noise level +1 dB. The highest of these levels is used as the Masking Criterion for that band. Note that proposed harmonization with ICAO regulations may result in these criteria being changed to Pre-Detection Noise +3 dB and Post-Detection Noise +3 dB for all aircraft.
5. Identification of "Masked" data; Each spectrum in the aircraft event is evaluated for Masking by comparing the one-third-octave-band levels against the Masking Criteria levels. A record is kept of which bands in each spectrum are Masked.

In cases where Slow exponential averaging is applied during the processing of linear time-averaged data, the identification of Masking should be done before averaging. After time-averaging, the Masking record for each band in the averaged spectrum should indicate a Masked condition if any of the linear samples used to create the averaged value are Masked (For continuous exponential time-averaging, if any of the linear samples within the 2-second averaging period are Masked, the averaged level is Masked).

6. Determination of Last Good Band; For each ½second spectral record, determine the highest-frequency Unmasked one-third-octave-band ("Last Good Band" or "LGB") by starting with the 630 Hz band and incrementing the band number until a Masked band is found. At that point, set LGB equal to the band below the Masked band. If both the 630 Hz band and the 800 Hz band are Masked, no Reconstruction of Masked Levels may be performed for that spectrum, and the eight bands between 630 Hz and 10 kHZ inclusive should be left as-is and identified as Masked.
7. Correction of Valid Levels for Background Noise; In each ½second spectrum, for each band up to and including LGB, perform an Energy-Subtraction of the Valid Pre-Detection level from the measured level.

    $10*\log_{10}[10\text{^}(\text{Aircraft level} / 10)-10\text{^}(\text{Pre-Detection Level} / 10)]$

Energy-Subtraction should be performed on all Valid data, not just on levels within 10 dB of the Masking Criteria.

8. Adjustment of Valid Data for Measurement Conditions; Before any Reconstruction can be done for Masked data, Valid data which have been adjusted for the presence of Pre-Detection Noise must also be adjusted for frequency-dependent elements such as: system frequency-response, microphone pressure-response and free-field response, windscreen incidence-dependent insertion loss, and analyzer bandwidth error. These adjustments should not be applied to Masked data.
9. Reconstruction of Low-Frequency Masked Bands; For cases where a single Masked Low-Frequency one-third-octave-band occurs between two adjacent Valid bands, the Masked band can be used as-is for subsequent processing, or the levels of the adjacent Adjusted bands may be arithmetically averaged, and the averaged level used in place of the Masked Level. If Masked Low-Frequency bands are found adjacent to other Masked Low-Frequency bands, these bands should be left as-is and identified as Masked. Note that proposed harmonization with ICAO regulations may allow / require that Low-Frequency levels between the level of the Pre-Detection Noise and Pre-Detection Noise +3 dB be set equal to the Pre-Detection Noise level.
10. Reconstruction of Levels for Masked High-Frequency bands; Extrapolation is used to Reconstruct Masked one-third-octave-bands above LGB for each spectral record as described below. Note that emission coordinates must have already been calculated for each record, since the extrapolation is dependent on propagation distance.

    - For a spectrum where LGB is located at or above the 2 kHz one-third-octave-band, the Frequency Extrapolation method is used (This method reconstructs Masked High-Frequency bands starting with the level associated with LGB in the same

spectrum). Reconstruct the levels for all bands above LGB using the following equation:

$$SPL_{i,k} = SPL_{i',k} + (SR_k/1000)*(\alpha_{i',k} - \alpha_{i,k})$$

Where: $SPL_{i,k}$ is the extrapolated level for one-third-octave-band i and spectral record number k; $SPL_{i',k}$ is the Adjusted Level for LGB; SR_k is the propagation distance from the aircraft to the microphone at time of emission (in feet) for spectral record number k; $\alpha_{i,k}$ is the atmospheric absorption coefficient (in decibels per 1000 ft) for one-third-octave-band i and spectral record number k; and $\alpha_{i',k}$ is the atmospheric absorption coefficient (in decibels per 1000 ft) for LGB and spectral record number k.
This equation assumes a flat spectrum at the noise source. An additional fixed slope may be applied, based on test data, but it must be approved by FAA. Note that proposed harmonization with ICAO may result in a significant modification to this procedure, based on the assumption that the aircraft noise spectrum is flat at a distance of 60 meters from the aircraft under reference atmospheric conditions.

- For a spectrum where LGB is at or between the 630 Hz one-third-octave-band and the 1.6 kHz band, the Time Extrapolation method is used (This method Reconstructs a Masked band in a spectrum from the closest record in which that band is Valid). Reconstruct levels for all one-third-octave-bands above LGB using the following equation:

$$SPL_{i,k} = SPL_{i,k'} + \{[(SR_{k'}/1000)*\alpha_{i,k'}] - [(SR_{i,k}/1000)*\alpha_{i,k}]\} + 20*\log_{10}(SR_{k'}/SR_k)$$

Where: i is the one-third-octave-band to be time-extrapolated; k is the spectral record number requiring Reconstruction of band i; k' is the spectral record number nearest in time to record number k, in which band i is Valid; $SPL_{i,k}$ is the Reconstructed Level for one-third-octave-band i and spectral record number k; $SPL_{i,k'}$ is the Adjusted Level for one-third-octave-band i and spectral record number k'; SR_k is the propagation distance from the aircraft to the microphone at time of emission of spectral record number k (in feet); $SR_{k'}$ is the propagation distance from the aircraft to the microphone at time of emission of spectral record number k' (in feet); $\alpha_{i,k}$ is the atmospheric absorption coefficient (in decibels per 1000 ft) for one-third-octave-band i and spectral record number k; and $\alpha_{i,k'}$ is the atmospheric absorption coefficient (in decibels per 1000 ft) for one-third-octave-band i and spectral record number k'.

An additional adjustment for directivity of the aircraft noise may be made dependent on emission angle if supported by test data and approved by FAA. Otherwise, for time extrapolation purposes, aircraft noise generation is considered to be omnidirectional.

A1.5 Limitations and Requirements for Background Noise Correction:

Any method of correcting for the effects of Background Noise must be validated by VNTSC and approved by FAA. The example correction procedure presented above represents an approved method, and is the one most commonly used by applicants. Limitations and requirements for all methodologies are described below:

- The applicant must demonstrate that no significant tones occur in Masked data regions by means of narrow-band analysis or other methods.
- Neither frequency-dependent corrections nor Energy-Subtraction of Pre-Detection levels should be applied to Masked data.
- Whenever levels at or below 0 dB occur, whether as part of the original analysis or as a result of the Background Noise correction, their values must be maintained and included in

all relevant calculations. Such levels can become significant during the adjustment of test data to reference conditions, especially over long propagation distances, where the effects of atmospheric absorption on higher frequency data can produce large one-third-octave-band corrections.

- When consecutive one-third-octave-bands in the range of 800 Hz to 2 kHz inclusive are Masked, time-extrapolation must be performed on all consecutive, Masked bands above 630 Hz.
- When consecutive one-third-octave-bands in the range of 2.5 kHz to 10 kHz inclusive are Masked, and when no consecutive bands are Masked in the region of 800 Hz to 2 kHz inclusive, frequency-extrapolation must be performed on all consecutive Masked bands above 2 kHz.
- For cases where a single Masked one-third-octave-band occurs between two adjacent Valid bands, the Masked band can be used as-is for subsequent processing, or the levels of the adjacent Adjusted bands may be arithmetically averaged, and the averaged level used in place of the Masked Level.

A1.6 Other Considerations:

Rejection of Spectra Due to Masking; The following conditions render a spectrum invalid (Note: If an invalid spectrum occurs within the 10 dB-down period, the event is invalid, and cannot be used for aircraft noise certification purposes):

(1.) After any Reconstruction of Masked bands, more than four one-third-octave-bands retain Masked values.

(2.) For records within one second (five ½second data records) of the record associated with the PNLTmax spectrum, when more than four High-Frequency bands require Reconstruction. (Or if LGB is located at or below the 4 kHz one-third-octave-band when the example Background Noise correction procedure presented above is used).

Special Tone-Correction Considerations Due to Masking; When the maximum tone-correction for a one-third-octave spectrum occurs at a Masked or Reconstructed band, the tone-correction for that spectrum can not simply be set to zero. The maximum tone-correction for the spectrum must be computed, taking Masked or extrapolated levels into consideration. Any tone correction resulting from correction for Background Noise may be eliminated by one of the following methods as appropriate:

- When the example Background Noise correction procedure presented here is used, the band labeled as LGB should be treated as the last band of the calculation, in the manner prescribed for the 10 kHz band in Appendix B of FAR 36, including calculation of a new slope for the band above LGB that equals the slope of the band at LGB (s'(LGB+1,k)=s'(LGB,k)) in Step 5 of the tone-correction procedure.
- For tone-corrections that occur at one-third-octave-bands that are Masked or Reconstructed, set F equal to 0 in Step 9 of the tone-correction procedure, and recalculate the maximum tone-correction for that spectrum.
- For tones that occur due to the presence of Masked or Reconstructed bands, compute new SPL'' values for the Masked or Reconstructed bands in Tone-correction procedure Step 7. Then recalculate the maximum tone-correction for that spectrum.

(See Paragraphs 153.12 through 153.13 for more information concerning tone correction.)

Handling of Masked Data in Reference-Day Data Set; For any one-third-octave-band spectrum corrected to reference conditions, all bands, including ones containing Masked or Reconstructed Levels (including values less than 0 dB) must be corrected. The special tone-correction considerations listed above apply to both test-day and reference-day data sets.

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